CLAIMS

1. Apparatus for manipulating the phase space of at least one charged particle, comprising at least one electrode arranged on a surface and connected to a power supply capable of applying both an alternating current voltage and a direct current voltage so as to form a potential which provides a region of phase space manipulation to one side of the electrode surface, wherein said electrode or electrodes do not surround a charged particle whose phase space is manipulated in use.

2. The apparatus of claim 1, further comprising pressure control means to control the pressure of the space surrounding the electrodes.

3. The apparatus of claim 2, wherein the pressure control means comprises a sealable chamber and gas pump means capable of introducing and extracting gases from the chamber.

4. The apparatus of any of claims 1-3, wherein the power supply is operable to vary the alternating current and direct current voltages applied.

5. The apparatus of any preceding claim, wherein the power supply is operable to individually alter the amplitude, waveform, and frequency of the alternating current voltage, and is operable to alter the magnitude of the direct current voltage.

6. The apparatus of any preceding claim, wherein the potential is an effective potential.

7. The apparatus of any preceding claim, wherein the region of phase space manipulation comprises a particle trapping region, wherein a particle is constrained in a specific spatial area.

8. The apparatus of any preceding claim, wherein the region of phase space manipulation comprises a particle guide region, wherein a particle's motion is restrained by at least one degree of freedom.

9. The apparatus of any preceding claim, wherein a plurality of electrodes are provided.

10. The apparatus of claim 9, wherein the electrodes are arranged in an array such that the at least one particle is situated to one side of the array.

11. The apparatus of claim 10, wherein the array is substantially planar.

12. The apparatus of claim 10, wherein the array is hemispherical.

13. The apparatus of any of claims 1-8, wherein a single electrode is provided, and is surrounded by a plane held at a constant potential.

14. The apparatus of claim 13, wherein the electrode is circular.

15. The apparatus of claim 13 or claim 14, wherein the plane is earthed.

16. The apparatus of claim 14 or claim 15, wherein the frequency of alternating current voltage applied to the circular electrode is of a frequency having a period that is less than the time taken for light to pass over the diameter of the circular electrode.

17. The apparatus of any preceding claim, wherein the voltages applied to adjacent first and second sets of electrodes in a planar array can be varied such that the at least one particle can be moved from the particle trapping region provided by the first set of electrodes to the particle trapping region provided by the second set of electrodes.

18. The apparatus of claim 17, wherein at least one particle can be moved from a first trapping region provided by a first set of electrodes to a second trapping region provided by a second set of electrodes, wherein the voltages applied to the sets of electrodes can be changed from an initial, to an intermediate and then to a final configuration, and wherein;

in an initial configuration, a first set of electrodes is biased to a holding voltage to form a first particle trapping region to trap at least one particle therein, and an adjacent second set of electrodes is biased to zero volts;

in an intermediate configuration, both sets of electrodes are biased to the holding voltage to form a merged particle trapping region that traps the at least one particle;

in a final configuration, the first set of electrodes is biased to zero volts, and the second set of electrodes is biased to the holding voltage to form a second particle trapping region, that traps the at least one particle.

19. The apparatus of claim 18, wherein the process of moving at least one particle from a first trapping region provided by a first set of electrodes to a second trapping region provided by a second set of electrodes is repeatable to move the at least one particle along a chosen path on the planar array.

20. The apparatus of claim 19, wherein the planar array is formed using printed circuit board, lithographic, or focussed ion beam technology.

21. The apparatus of any of claims 1-16, wherein a series of electrodes are provided, the voltages applied to which are controllable such that the at least one particle can be moved from a first particle trapping region to a second particle trapping region, wherein the first trapping region is larger than the second trapping region.

22. The apparatus of claim 21, wherein the voltages applied to the electrodes are controllable such that

the at least one particle can be moved between a plurality of successively smaller trapping regions.

23. The apparatus of claim 21 or claim 22, wherein the series of electrodes comprises a plurality of concentrically arranged circular electrodes.

24. The apparatus of claim 23, wherein, in an initial state, every electrode has a combination of alternating current and direct current voltages applied such that at least one particle is trapped in a first trapping region;

the voltage applied to the outer electrode can be changed such that, in an intermediate state, the at least one particle is trapped in a first intermediate trapping region provided by the remaining inner electrodes; and

the voltage applied to the electrode adjacent to the outer electrode can be changed such that in a final state, the at least one particle is trapped in a second trapping region provided by the innermost electrode.

25. The apparatus of claim 24, wherein, in the transitions from the initial to intermediate and the intermediate to final states, the outer and adjacent electrodes respectively are set to zero volts.

26. The apparatus of claim 24 or claim 25, wherein a plurality of electrodes can each provide a further intermediate trapping region, such that, between the initial state and the final state, the at least one

particle passes through a plurality of intermediate states, being trapped in successively smaller intermediate trapping regions.

27. The apparatus of any of claims 21-23, wherein, in an initial state, an outermost electrode has a first combination of alternating current and direct current voltages applied, and a background voltage is applied to the remaining electrodes such that, in an initial state, at least one particle is trapped in a first trapping region;

the electrode adjacent to the outer electrode can be set to the first combination of voltages and the background voltage is applied to the outer electrode such that, in an intermediate state, the at least one particle is trapped in a first intermediate trapping region; and

the innermost electrode can be set to the first combination of voltages and the background voltage is applied to the adjacent electrode such that, in a final state, the at least one particle is trapped in a second trapping region.

28. The apparatus of claim 27, wherein the background voltage is zero volts.

29. The apparatus of claim 27 or claim 28, wherein a plurality of electrodes is provided such that, between the initial state and the final state, the at least one particle passes through a plurality of intermediate states, being trapped in successively smaller intermediate trapping regions.

30. The apparatus of any of claims 23-29 when dependent on claim 23, wherein the innermost electrode is provided with an aperture; arranged such that:

when the at least one particle is in the final state, a voltage is applied to the aperture such that the at least one particle is urged through the aperture.

31. The apparatus of claim 30, wherein each side of the aperture is differentially pumped so that a gas passing through the aperture undergoes a supersonic expansion, so as to cool the particles that are urged through the aperture.

32. The apparatus of any preceding claim, wherein the voltages applied to an electrode are such that one type of charged particle can be distinguished from another.

33. The apparatus of claim 32, wherein different types of charged particle are trapped at different distances perpendicularly from the surface of the electrode.

34. The apparatus of claim 33, wherein the distance is dependent on the charge and/or mass of the charged particle.

35. The apparatus of claim 34, wherein a first type of charged particle is trapped at a first

perpendicular distance from the electrode, and a second type of charged particle is trapped at a second perpendicular distance from the electrode, wherein the mass of the first charged particle is greater than the mass of the second charged particle, and the second perpendicular distance is greater than the first perpendicular distance.

36. The apparatus of claim 35, wherein at least one particle trapped at the second perpendicular distance is subject to the potential formed by a voltage sequence applied to a second set of electrodes.

37. The apparatus of claim 36, wherein the voltage sequence applied to the second set of electrodes is such as to transport said at least one particle from one trapping region to another along a predetermined path.

38. The apparatus of claim 36 or claim 37, wherein the dimensions of the second set of electrodes are of a much larger scale than the dimensions of the trap electrode.

39. The apparatus of any of claims 32-38, wherein an aperture is provided on an electrode such that the type of particle that is closest to the surface of the electrode can pass through the aperture.

40. The apparatus of claim 39, wherein each side of the aperture is differentially pumped so that a gas

passing through the aperture undergoes a supersonic expansion, so as to cool the particles that are urged through the aperture.

41. The apparatus of any preceding claim, wherein the voltages applied to an electrode can be changed such that a trapped particle moves in a direction perpendicular to the plane of the electrode.

42. The apparatus of claim 41, wherein at least one trapped particle can be lowered to a region where it will interact with at least one other particle; and

the particles that result from the interaction can then be raised up again, together with particles that have not interacted.

43. The apparatus of claim 41 or claim 42, wherein the electrode is formed with an aperture and the applied voltage can be changed to bring a particle close to the aperture; and

a voltage is applied to the aperture such that the particle is urged through the aperture.

44. The apparatus of claim 43, wherein each side of the aperture is differentially pumped so that a gas passing through the aperture undergoes a supersonic expansion, so as to cool the particles that are urged through the aperture.

45. The apparatus of any of claims 41-44, wherein an array of electrodes is provided, the voltages applied to which trap a first type of particle which

can interact with a second type of particle, to form a reactant particle which falls to the bottom of a trap and is swept away through an extraction hole.

46. The apparatus of claim 45, wherein the array of electrodes further comprises at least one aperture for the extraction of trapped particles.

47.. The apparatus of claim 46, wherein each electrode comprises one aperture.

48. The apparatus of claim 47, wherein the reactant particle is accelerated through a potential and detected so that the position of the original first type of particle can be detected.

49. A method for manipulating the phase space of at least one charged particle, wherein a combination of alternating current and direct current voltages applied to an electrode forms a potential which provides a region of phase space manipulation, and wherein the at least one charged particle is situated to one side of the electrode surface, wherein said electrode or electrodes do not surround a charged particle whose phase space is manipulated in use.

50. The method of claim 49, further comprising the step of controlling the pressure of the space surrounding the electrodes.

51. The method of claim 50, wherein the pressure control means comprises a sealable chamber and gas pump means capable of introducing and extracting gases from the chamber.

52. The method of any of claims 49-51, wherein the power supply is operable to vary the alternating current and direct current voltages applied.

53. The method of any of claims 49-52, wherein the power supply is operable to individually alter the amplitude, waveform, and frequency of the alternating current voltage, and is operable to alter the magnitude of the direct current voltage.

54. The method of any of claims 49-53, wherein the potential is an effective potential.

55. The method of any of claims 49-54, wherein the region of phase space manipulation comprises a particle trapping region, wherein a particle is constrained in a specific spatial area.

56. The method of any of claims 49-55, wherein the region of phase space manipulation comprises a particle guide region, wherein a particle's motion is restrained by at least one degree of freedom.

57. The method of any of claims 49-56, wherein a plurality of electrodes are provided.

58. The method of claim 57, wherein the electrodes are arranged in an array such that the at least one particle is situated to one side of the array.

59. The method of claim 58, wherein the array is substantially planar.

60. The method of claim 58, wherein the array is hemispherical.

61. The method of any of claims 49-56, wherein a single electrode is provided, and is surrounded by a plane held at a constant potential.

62. The method of claim 61, wherein the electrode is circular.

63. The method of claim 61 or claim 62, wherein the plane is earthed.

64. The method of claim 62 or claim 63, wherein the frequency of alternating current voltage applied to the circular electrode is of a frequency having a period that is less than the time taken for light to pass over the diameter of the circular electrode.

65. The method of any of claims 49-64, wherein the voltages applied to adjacent first and second sets of electrodes in a planar array can be varied such that the at least one particle can be moved from the particle trapping region provided by the first set

of electrodes to the particle trapping region provided by the second set of electrodes.

66. The method of claim 65, wherein at least one particle is moved from a first trapping region provided by a first set of electrodes to a second trapping region provided by a second set of electrodes, wherein the voltages applied to the sets of electrodes is changed from an initial, to an intermediate and then to a final configuration, and wherein;

in an initial configuration, a first set of electrodes is biased to a holding voltage to form a first particle trapping region to trap at least one particle therein, and an adjacent second set of electrodes is biased to zero volts;

in an intermediate configuration, both sets of electrodes are biased to the holding voltage to form a merged particle trapping region that traps the at least one particle;

in a final configuration, the first set of electrodes is biased to zero volts, and the second set of electrodes is biased to the holding voltage to form a second particle trapping region, that traps the at least one particle.

67. The method of claim 66, wherein the process of moving at least one particle from a first trapping region provided by a first set of electrodes to a second trapping region provided by a second set of electrodes is repeatable to move the at least one particle along a chosen path on the planar array.

68. The method of claim 67, wherein the planar array is formed using printed circuit board, lithographic, or focussed ion beam technology.

69. The method of any of claims 49-64, wherein a series of electrodes are provided, the voltages applied to which are controllable such that the at least one particle can be moved from a first particle trapping region to a second particle trapping region, wherein the first trapping region is larger than the second trapping region.

70. The method of claim 69, wherein the voltages applied to the electrodes are controllable such that the at least one particle can be moved between a plurality of successively smaller trapping regions.

71. The method of claim 69 or claim 70, wherein the series of electrodes comprises a plurality of concentrically arranged circular electrodes.

72. The method of claim 71, wherein, in an initial state, every electrode has a combination of alternating current and direct current voltages applied such that at least one particle is trapped in a first trapping region;

the voltage applied to the outer electrode is changed such that, in an intermediate state, the at least one particle is trapped in a first intermediate trapping region provided by the remaining inner electrodes; and

the voltage applied to the electrode adjacent to the outer electrode is changed such that in a final state, the at least one particle is trapped in a second trapping region provided by the innermost electrode.

73. The method of claim 72, wherein, in the transitions from the initial to intermediate and the intermediate to final states, the outer and adjacent electrodes respectively are set to zero volts.

74. The method of claim 72 or claim 73, wherein a plurality of electrodes each provide a further intermediate trapping region, such that, between the initial state and the final state, the at least one particle passes through a plurality of intermediate states, being trapped in successively smaller intermediate trapping regions.

75. The method of any of claims 69-71, wherein, in an initial state, an outermost electrode has a first combination of alternating current and direct current voltages applied, and a background voltage is applied to the remaining electrodes such that, in an initial state, at least one particle is trapped in a first trapping region;

the electrode adjacent to the outer electrode is set to the first combination of voltages and the background voltage is applied to the outer electrode such that, in an intermediate state, the at least one particle is trapped in a first intermediate trapping region; and

the innermost electrode is set to the first combination of voltages and the background voltage is applied to the adjacent electrode such that, in a final state, the at least one particle is trapped in a second trapping region.

76. The method of claim 75, wherein the background voltage is zero volts.

77. The method of claim 75 or claim 76, wherein a plurality of electrodes is provided such that, between the initial state and the final state, the at least one particle passes through a plurality of intermediate states, being trapped in successively smaller intermediate trapping regions.

78. The method of any of claims 71-77 when dependent on claim 71, wherein the innermost electrode is provided with an aperture; and

when the at least one particle is in the final state, a voltage is applied to the aperture such that the at least one particle is urged through the aperture.

79. The method claim 78, wherein each side of the aperture is differentially pumped so that a gas passing through the aperture undergoes a supersonic expansion, so as to cool the particles that are urged through the aperture.

80. The method of any of claims 49-79, wherein the voltages applied to an electrode are such that one

type of charged particle can be distinguished from another.

81. The method of claim 80, wherein different types of charged particle are trapped at different distances perpendicularly from the surface of the electrode.

82. The method of claim 81, wherein the distance is dependent on the charge and/or mass of the charged particle.

83. The method of claim 82, wherein a first type of charged particle is trapped at a first perpendicular distance from the electrode, and a second type of charged particle is trapped at a second perpendicular distance from the electrode, wherein the mass of the first charged particle is greater than the mass of the second charged particle, and the second perpendicular distance is greater than the first perpendicular distance.

84. The method of claim 83, wherein at least one particle trapped at the second perpendicular distance is subject to the potential formed by a voltage sequence applied to a second set of electrodes.

85. The method of claim 84, wherein the voltage sequence applied to the second set of electrodes is such as to transport said at least one particle from

one trapping region to another along a predetermined path.

86. The method of claim 84 or claim 85, wherein the dimensions of the second set of electrodes are of a much larger scale than the dimensions of the trap electrode.

87. The method of any of claims 80-86, wherein an aperture is provided on an electrode such that the type of particle that is closest to the surface of the electrode can pass through the aperture.

88. The method of claim 87, wherein each side of the aperture is differentially pumped so that a gas passing through the aperture undergoes a supersonic expansion, so as to cool the particles that are urged through the aperture.

89. The method of any of claims 49-88, wherein the voltages applied to an electrode can be changed such that a trapped particle moves in a direction perpendicular to the plane of the electrode.

90. The method of claim 89, wherein at least one trapped particle can be lowered to a region where it will interact with at least one other particle; and

the particles that result from the interaction can then be raised up again, together with particles that have not interacted.

91. The method of claim 89 or claim 90, wherein the electrode is formed with an aperture and the applied voltage can be changed to bring a particle close to the aperture; and

a voltage is applied to the aperture such that the particle is urged through the aperture.

92. The method of claim 91, wherein each side of the aperture is differentially pumped so that a gas passing through the aperture undergoes a supersonic expansion, so as to cool the particles that are urged through the aperture.

93. The method of any of claims 89-92, wherein an array of electrodes is provided, the voltages applied to which trap a first type of particle which can interact with a second type of particle, to form a reactant particle which falls to the bottom of a trap and is swept away through an extraction hole.

94. The method of claim 93, wherein the array of electrodes further comprises at least one aperture for the extraction of trapped particles.

95. The method of claim 94, wherein each electrode comprises one aperture.

96. The method of claim 95, wherein the reactant particle is accelerated through a potential and detected so that the position of the original first type of particle can be detected.

This Page is Inserted by IFW Indexing and Scanning Operations and is not part of the Official Record

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ BLACK BORDERS
- ☑ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES
- ☑ FADED TEXT OR DRAWING
- ☐ BLURRED OR ILLEGIBLE TEXT OR DRAWING
- ☐ SKEWED/SLANTED IMAGES
- ☐ COLOR OR BLACK AND WHITE PHOTOGRAPHS
- ☐ GRAY SCALE DOCUMENTS
- ☐ LINES OR MARKS ON ORIGINAL DOCUMENT
- ☐ REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY
- ☐ OTHER: ______________________

IMAGES ARE BEST AVAILABLE COPY.
As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.